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MEASURING SYSTEMS FOR ICE AND WIND LOADS ON A STEEL LIGHTHOUSE

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INTRODUCTION

A new type of lighthouse has been developed in Finland and the first two of them will be completed during 1973. The lighthouse is a steel pipe with average wall thickness of 20 mm. Its diameter is 3180 mm and total height 51 m. (Fig. 1) The first of them will be erected outside Kemi by ramming the pipe 15 meters into the bottom of Gulf of Bothnia.

Its light construction in comparison with the conventional concrete lighthouses requires more accuracy in determing loads, specifically due to ice, wind and waves, to which the lighthouse will be subjected. To have sufficient security with resonable cost of construction, the Finnish Administration of Navigation has ordered prolonged measurements in the lighthouse of Kemi.

TRANSDUCERS

The measuring system consists of three sets of transducers. One of them finds the total lateral load due to ice pressure, wind and waves against the pipe by measuring the bending strain in the pipe in two orthogonal directions near the sea bottom. The bending strains are measured with interchangeable staffs made of stainless steel. Semiconductor strain gauges (BLH type SNB 3-16-35-59) are bonded to them and they are moisture protected with plastic coating. (Fig. 2) Four staffs are bolted to the pipe in angles of 90 degrees apart of each other in the circumferential direction. The two strain gauges in the opposite sides of the pipe are electrically connected in the adjacent arms of a Wheatstone bridge. This temperature compensated bridge has a further advantage of greatly eliminating the linearity errors always present with semiconductor strain gauges and also the Wheatstone bridge itself (linearity error is less than 0.3 % of nominal value).

The inclination of the top of the lighthouse pipe is measured in two orthogonal directions with an apparatus schematically shown in fig. 3. It consists of a liquid vessel connected to two pipes. The level of the liquid surface in these pipes is measured with LVDT displacement transducers (Schaevitz model 100 DC-B), thus defining the inclinations. For inducing a suitable damping against lateral accelerations two cocks are fitted into the system. This type transducer suits only in measuring of static or slowly changing values of inclination. In order to pick up the dynamic parts of inclination variations, the displacement transducers are connected to a lever that has its bearings in the main frame. This lever resists rotations with its mass of inertia, thus measuring fast inclinations of the main frame. Because of springs the lever turns slowly to the inclination of the main frame while the liquid in the system flows from the vessel to the measuring pipe compensating the rotation of the lever. Thus the system has almost flat responce to inclinations in all frequences except some irregularities in frequences close to 0.1 Hz.

The third measured quantιυs are the lateral accelerations of the top of the lighthouse. They are measured with two linear servo accelerometers (Schaevitz model LSD-1) fitted in orthogonal directions.

MEASURING SYSTEM

A simplified block diagram of the whole measuring system is shown in fig. 4. The measuring period is three hours. During this period the above mentioned quantities, the lateral force (bending moment), inclination and acceleration, are measured in turn 22.5 times a second in two orthogonal directions. The two components (X and Y) are connected into a vector module forming the resultant $\sqrt{X^2 + Y^2}$ in analogue form.

At the same time the three decade counter, in which the previous maximum value of the quantity now under measurement is registered in digital form, is fed through a digital-analogue converter into a comparator together with the value of the output of the vector module, and if the latter value is greater, it opens a gate into the counter for the 100 kHz clock. The counter is counted up so far that the output of the D/A converter reaches the value in the output of the vector module, and the gate will be closed. Thus a new maximum value is registered into the counter. If the reading of the counter will be greater than the measured value, the gate will remain closed and the content of the counter will stay unaltered.

If the registered new maximum was a value of force, its direction will be also registered. Therefore the sine of the angle of direction is counted in analogue form and registered in one counter in the some way as described above however starting with a zeroed counter.

At the end of a measuring period the registered maximum values of acceleration, inclination and force with its direction will be sent to the shore station by a wireless for further treatments, all the counters will be zeroed and a new measuring period started.

This measuring system developed by the Structural Division of Civil Engineering Department of Helsinki University of Technology is designed to work in temperature range from $-40^{o}C$ to $+40^{o}C$ and in humidity under 90 %. The total maximum errors in measured values will then be less than 5 % of nomin[al] values. Because the system is battery powered, special attention have been payed to minimise the current consumption by special selection of components and shared use of modules.

ACKNOWLEDGEMENTS

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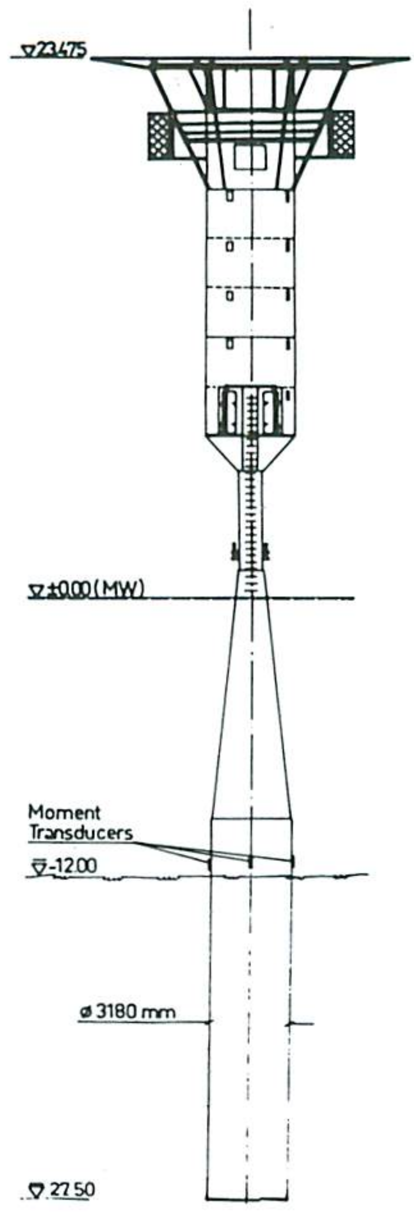

Figure 1. Lighthouse of Kemi.

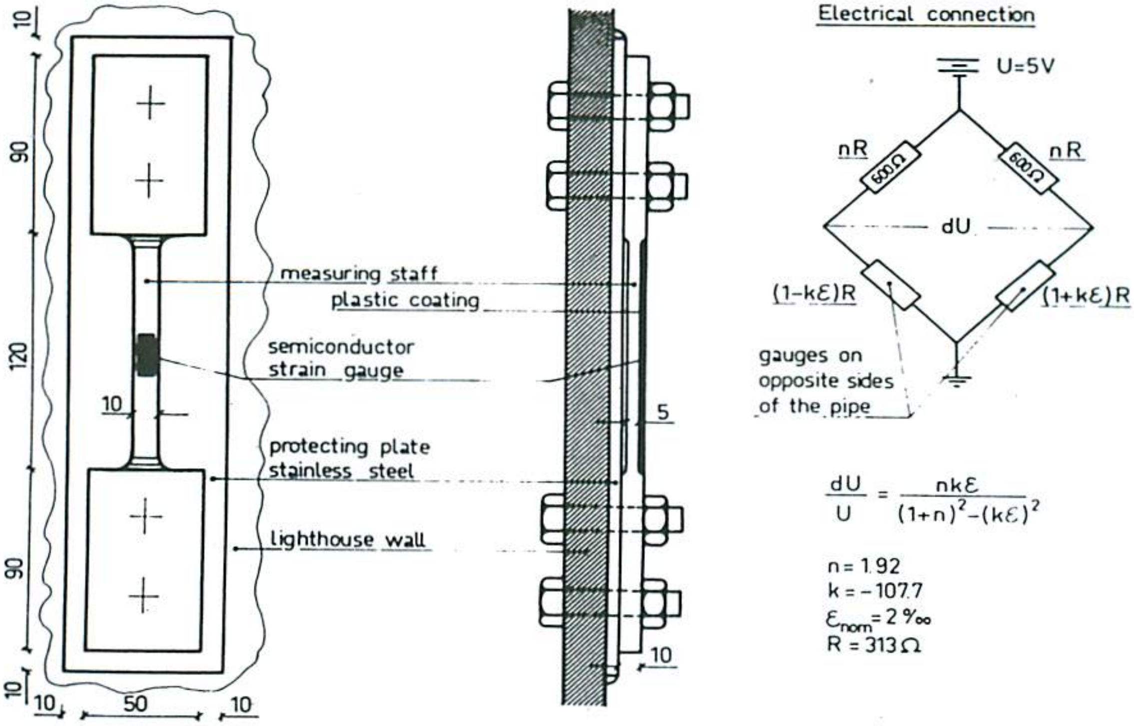

Figure 2. Moment transducer.

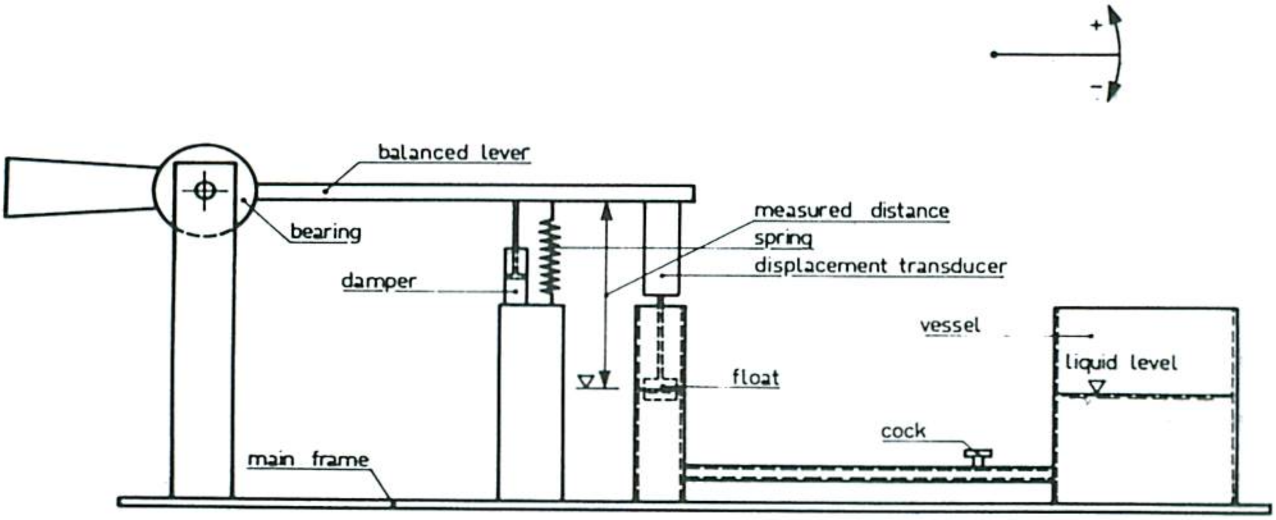

Figure 3. Inclination measuring apparatus.

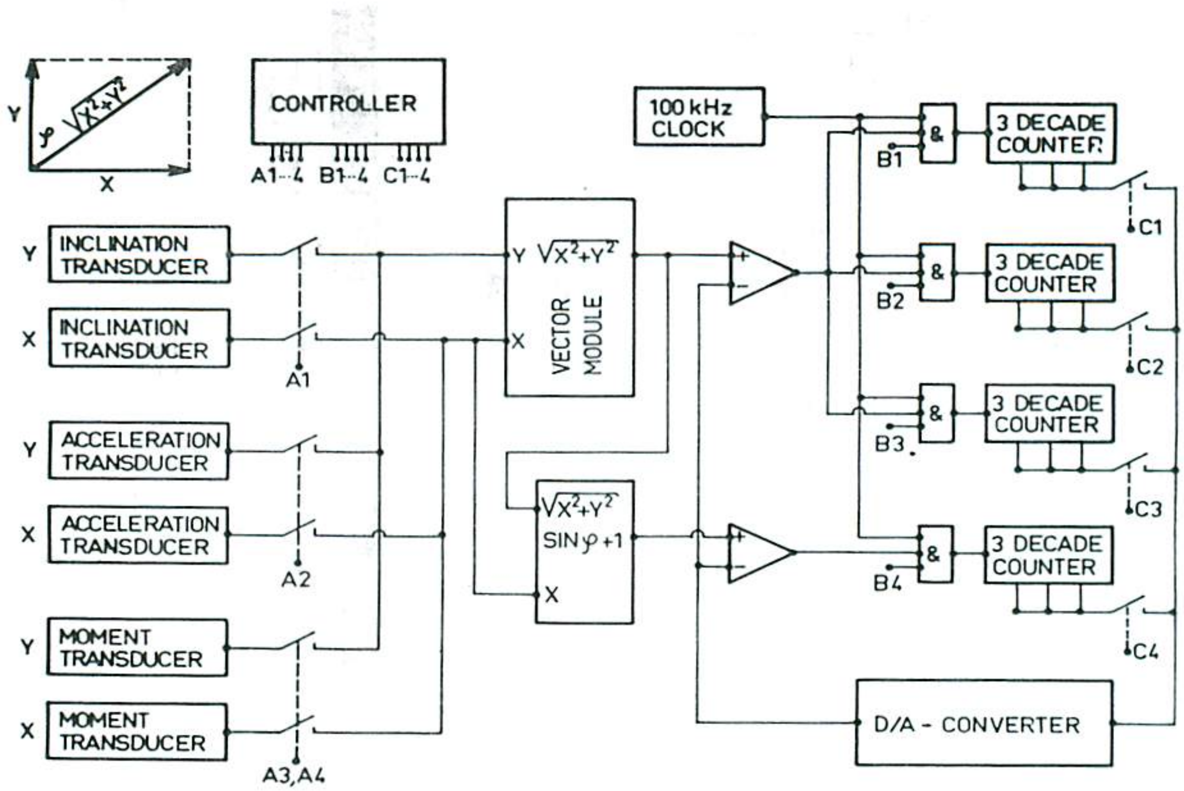

Figure 4. Block diagram of the measuring system.